ESD-TR-72-132

MTR-2074

DISCRETE CLUTTER MEASUREMENTS PROGRAM: OPERATIONS IN WESTERN MASSACHUSETTS

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MARCH 1972

Prepared for

DEPUTY FOR AWACS
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts

Project 4110
Prepared by
THE MITRE CORPORATION
Bedford, Massachusetts
Contract F19(628)-71-C-0002

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) The MITRE Corporation Bedford, Massachusetts	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

Discrete Clutter Measurements Program: Operations in Western Massachusetts

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)

William J. McEvoy

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
MARCH 1972	55	4

8a. CONTRACT OR GRANT NO. F19(628)-71-C-0002 b. PROJECT NO. 4110 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) ESD-TR-72-132 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) MTR-2074

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Electronic Systems Division, Air Force Systems Command, L. G. Hanscom Field, Bedford, Mass.

13. ABSTRACT

The MITRE Corporation has been conducting a clutter measurements program aimed at providing data for use in the AWACS program. Preliminary results, obtained at Boston Hill, suggested the need for a mobile radar in order to study the grazing and azimuthal angle dependence of discrete clutter. A truck-mounted radar facility has been constructed and operated in the western area of Massachusetts. This report describes the facility and the results obtained.

DD FORM 1 NOV 65 1473

Security Classification

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
CLUTTER						
DISCRETE CLUTTER						
RADAR MEASUREMENT						

Security Classification

FOREWORD

This report was prepared for the 411L System Project 1110 by The MITRE Corporation, Bedford, Massachusetts, under Contract Number F19628-71-C-0002. The Air Force program monitor was Captain Donald G. Tock, YWED. The experimental work leading to this report took place from June 1970 to October 1970, and the report was submitted on 17 April 1971.

REVIEW AND APPROVAL

Publication of this technical report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

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Deputy for AWACS

ABSTRACT

The MITRE Corporation has been conducting a clutter measurements program aimed at providing data for use in the AWACS program. Preliminary results, obtained at Boston Hill, suggested the need for a mobile radar in order to study the grazing and azimuthal angle dependence of discrete clutter. A truck-mounted radar facility has been constructed and operated in the western area of Massachusetts. This report describes the facility and the results obtained.

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INTRODUCTION

About two years ago several people involved in the MITRE AWACS program became concerned about the possible impact of discrete clutter upon radar design and performance. It was felt that if discretes, i.e., large isolated point targets, existed in any substantial measure, a severe penalty in radar performance was implied unless adequate means were provided in the radars and/or test instrumentation to handle discrete returns. Discrete detections would have the effect of greatly adding to the false alarm rate expected from distributed clutter.

Some workers in the AWACS program outside of MITRE believed, however, that discretes did not exist, in which case a clutter model based upon distributed clutter would be adequate for design purposes. The need then would thus be for more accurate determination of the parameters of a distributed or Rayleigh clutter model at S-band. Others thought that a modification of the Rayleigh model would account for "tails" on measured clutter distributions; such tails would reflect the abnormally high frequency of measurement of higher values of cross section.

It was concluded that an experimental program was needed at least to determine if discretes do exist at S-band. It was thought that a modest program could produce some useful data, particularly inasmuch as no data was known to exist at S-band. In the summer

of 1969, as a task of AWACS Project 4110, MITRE initiated an experimental discrete measurement program by locating a radar at the Boston Hill Field Station. This work was described in reference 1.

The data obtained at Boston Hill showed conclusively that discretes exist at S-band. The largest discretes, all above 10,000 m^2, were identified as vertical structures. In particular, twenty four of the twenty seven discretes observed to be greater than 10,000 m^2 were cylindrical water towers, located on hills with heights comparable to the altitude of the radar, and therefore observed at grazing angles close to zero.

Consideration was then given to means of controlling grazing and azimuthal angle in measurements in order to determine dependence on these parameters, and to extension of measurements to other areas. The helicopter was singled out as most suitable for conducting such experiments. But the cost of operation of a helicopter was judged to be great enough to merit an intermediate phase to the program, namely constructing a truck mounted experimental facility. A mobile radar could acquire some data at steeper grazing angles; the data could be obtained at a modest cost, and provide guidance in determining both the need and type of measurements to be made by helicopter-mounting the radar.

Using MITRE design and shop facilities, a vehicle was fitted out as a mobile experimental test facility. The facility has been operated at several sites in the western part of the State of Massachusetts and radar cross section measurements have been

made on discretes at grazing angles up to about eleven degrees. This report gives details of the results obtained with the mobile radar facility in the Adams/North Adams area of Massachusetts.

SECTION II

DESCRIPTION OF EQUIPMENT

A. VEHICLE AND PHYSICAL FACILITIES

The mobile experimental radar facility has an entirely self-sustaining capability permitting it to be used at sites where only minimal quality access roads are available. Figures 1, 2, 3 and 4 are views of the equipment in its operational and transport configurations.

The vehicle, a 2 - 1/2 ton, 6 x 6 combat cargo and troop carrier, was obtained as surplus property. An electronic operations shelter supplied with the truck was refurbished and fitted out as a laboratory with work bench and electronic tool and parts complements. A commercial gasoline powered 5 KVA, 115V, 60 hertz generator was procured and mounted on a shelf over the cab. (Subsequently, a trailered heavy duty generator was substituted after breakdown of the commercial unit in the field). Since it was intended to make the truck a self-contained ground check-out facility for helicopter experiments, a surplus gasoline powered 200 ampere, 28V dc generator was similarly mounted on the shelf over the cab in order to simulate a typical helicopter electrical bus. All power sources are "hard wired" through breakered distribution panels to service receptacles.

From the time of arrival at a site, the equipment can be made fully operational in about one hour by two technicians. The facility has provision for leveling the antenna on inclines of about ten degrees from front to back, and about four degrees side to side.

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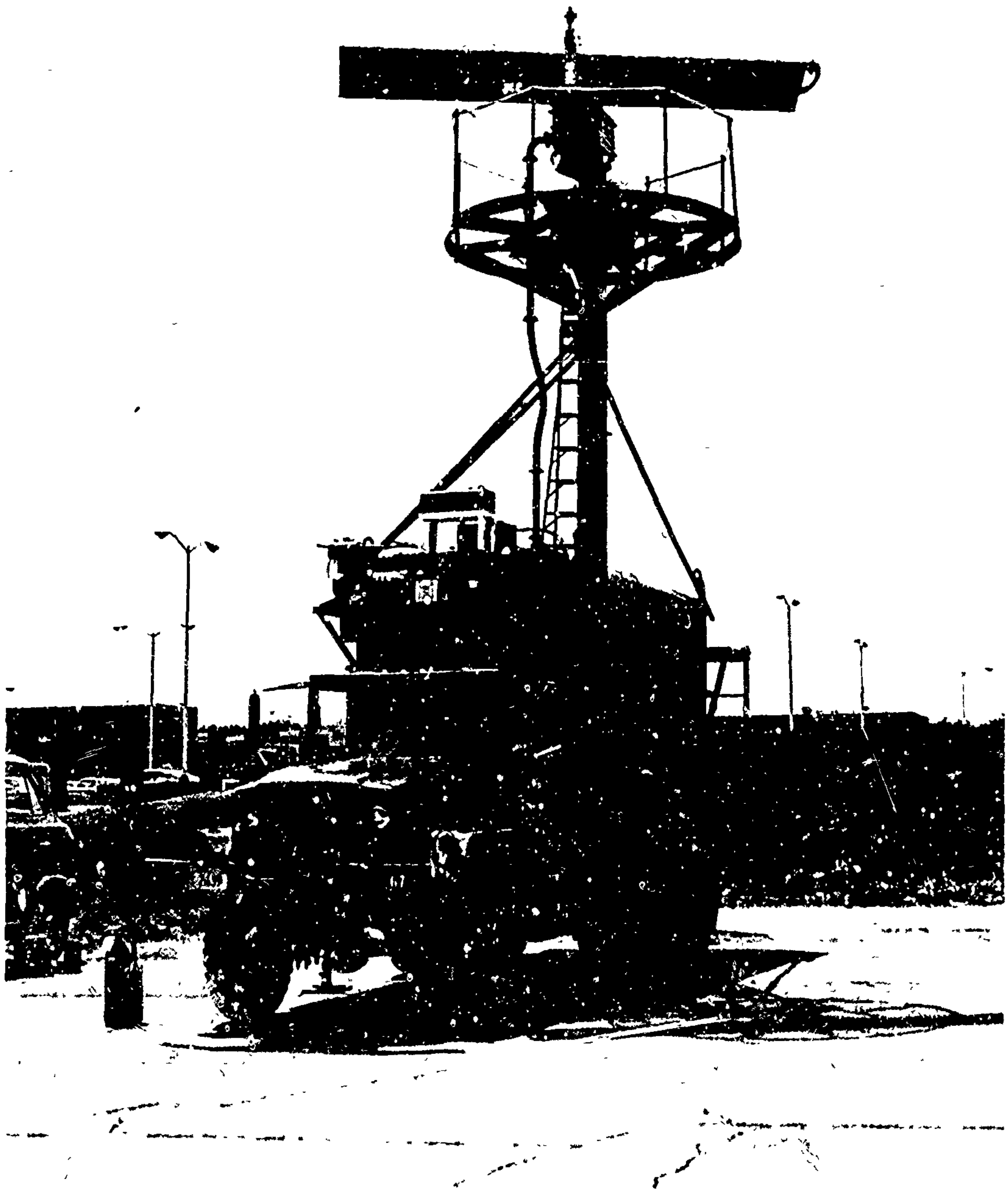


Figure I FRONT VIEW OF MOBILE RADAR FACILITY
IN THE OPERATIONAL CONFIGURATION

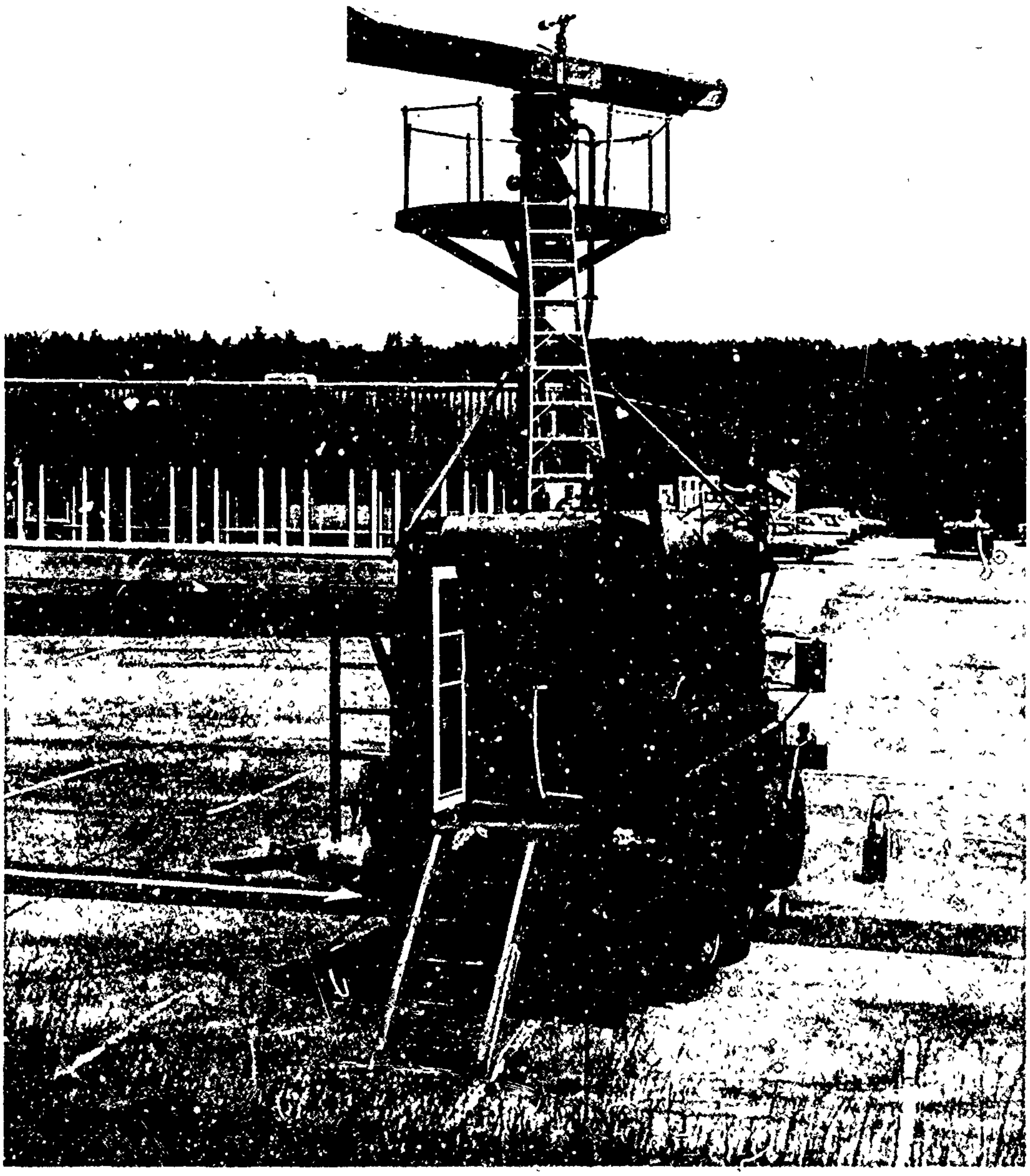


Figure 2 REAR VIEW OF MOBILE RADAR FACILITY
IN THE OPERATIONAL CONFIGURATION

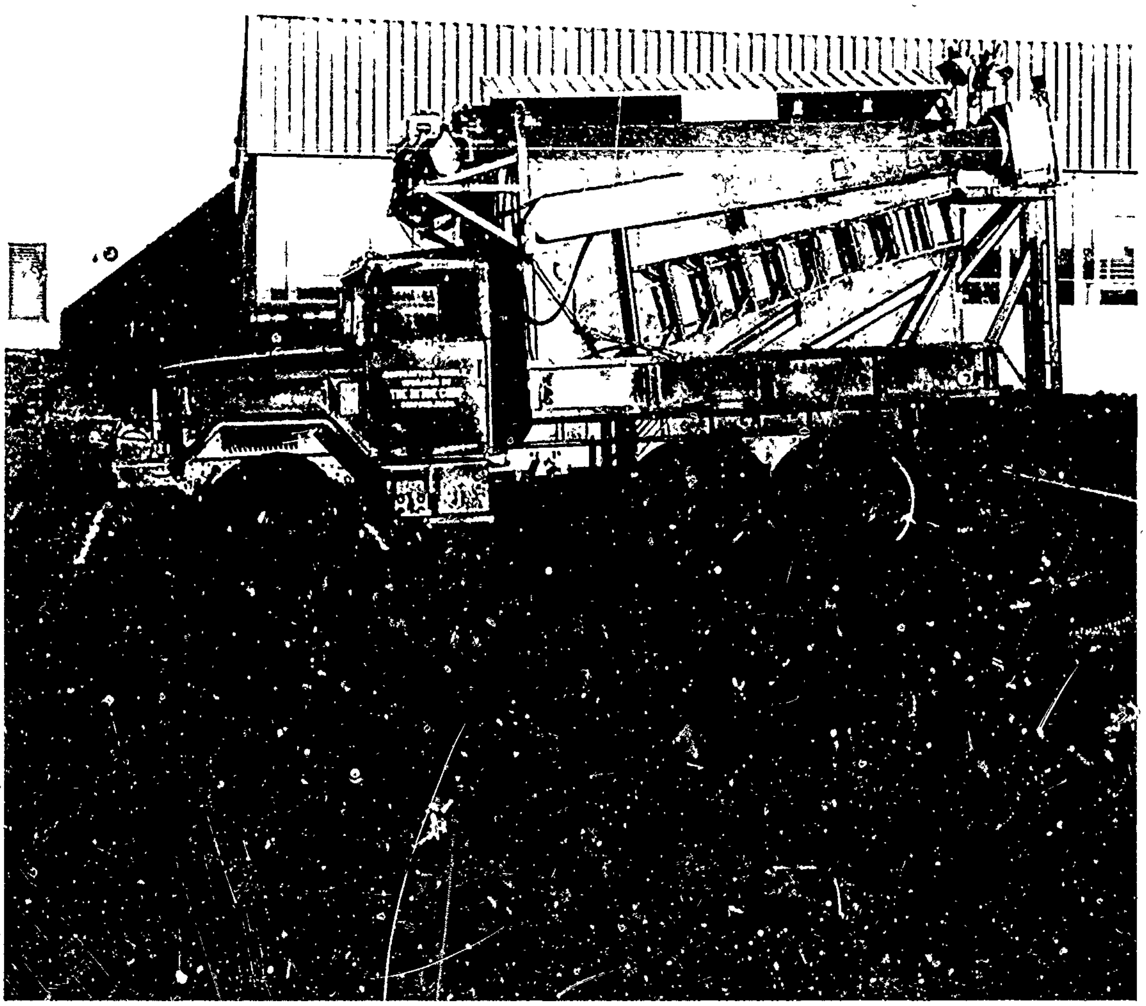


Figure 3 LEFT SIDE VIEW OF MOBILE RADAR FACILITY
IN THE TRAVELING CONFIGURATION

Figure 4 RIGHT SIDE VIEW OF MOBILE RADAR FACILITY
IN THE TRAVELING CONFIGURATION

The antenna height above the ground is 25 feet, adequate for clearance above most obstructions including tree lines. Stability of the antenna is provided by hydraulic jacks which take body weight off the truck springs.

The antenna, a 12 - 1/2 foot slotted waveguide array, is transported on the roof of the cabin. The pedestal which contains the rotary joint and drive motor is permanently mounted on a "boom" which is lowered in transport to rest upon a carrying shelf. The boom is pivoted on the left front corner of the cabin, and is erected by means of a hydraulic piston after the personnel platform and antennas are assembled. Braces to the right front and left rear corners of the cabin lock the boom in a vertical position. Levels on the boom permit adjustment of the braces so that the antenna is horizontal in the event the truck is on a grade. The personnel platform, reached by ladder from the roof of the cabin, can accommodate two observers. Communications from the antenna to the cabin is by means of an "intercom".

B. INSTRUMENTATION

The mobile experimental radar facility contains essentially the same instrumentation as that utilized in the fixed installation at Boston Hill[2]. Consequently, only a brief discussion will be given here. Significant differences will be noted. Referring to Figure 5, the instrumentation system block diagram, three sections of the instrumentation system are identified for convenience in discussion: "Radar Section", "Test Signal Generator Section" and "Measurement Section".

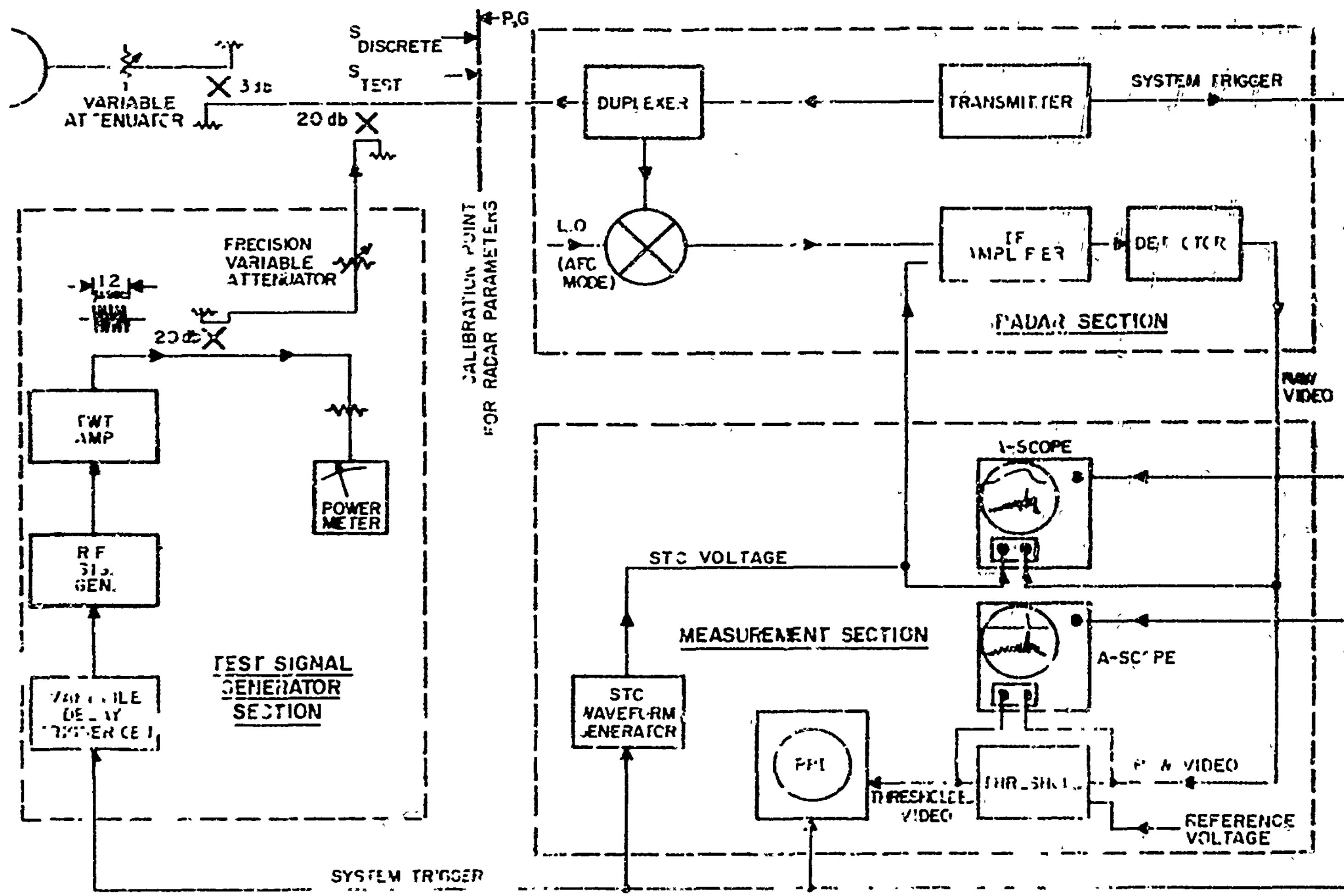


Figure 5 INSTRUMENTATION SYSTEM BLOCK DIAGRAM

The Radar Section consists of an S-band non-coherent radar, RCA type CRM-N2C-30, with major parameters as given in Table I, and shown in block diagram form in Figure 6. The radar parameters of peak power and antenna gain were measured at the reference plane indicated in Figure 5 and include correction for wave guide loss. A fixed 3 db power divider reduces the transmitter power to a value within the rating of the variable attenuator, the need for which is described below. The range equation using measured radar parameters, and including the 3 db power divider loss, is plotted in Figure 7. Observe that a quantity σ_e, or "effective" cross section is defined. It is the product of the true radar cross section and the pattern propagation factor, F, a quantity which is explicitly unknown in all measurements. Thus, a measurement of S, the returned signal power from a discrete and R, the range to the discrete, are used to measure the quantity σ_e. The values of radar cross section cited should be interpreted as σ_e unless otherwise stated.

The Test Signal Generator Section provides the ability to insert a test pulse of known power at any range of interest. Such a pulse is used primarily to calibrate the receiver from signal in to "raw video" out.

The Measurement Section provides the capability of (a) generating a sensitivity time control (STC) voltage which gain controls the I. F. amplifier, and (b) displaying radar outputs for measurement and observation.

An important feature of the operation of the radar is the removal of the range dependence of discrete returns. The STC generator

Table 1 Radar Parameters

Frequency:	3052 Mhz
Peak Power:	23.5 Kw*
Pulse Length:	0.4usec** (Range Resolution: 200 ft)
Pulse Repetition Rate:	1 Khz **
Antenna:	
Polarization -	Horizontal
Vertical Beamwidth -	20 degrees
Horizontal Beamwidth -	2 degrees
Gain -	28.4 db*
Side Lobes -	28 db, one-way (max)
Rotation Rate -	Variable to 13 r.p.m.
I. F. Amplifier:	
Type	Linear, with voltage-controlled gain
Center Frequency	30 Mhz
Bandwidth -	3 Mhz **

*See Figure 1 for definition of reference planes.

**The radar has an alternate mode with a 0.1-μsec pulse width and a 2 Khz repetition rate which was not utilized in the experiment.

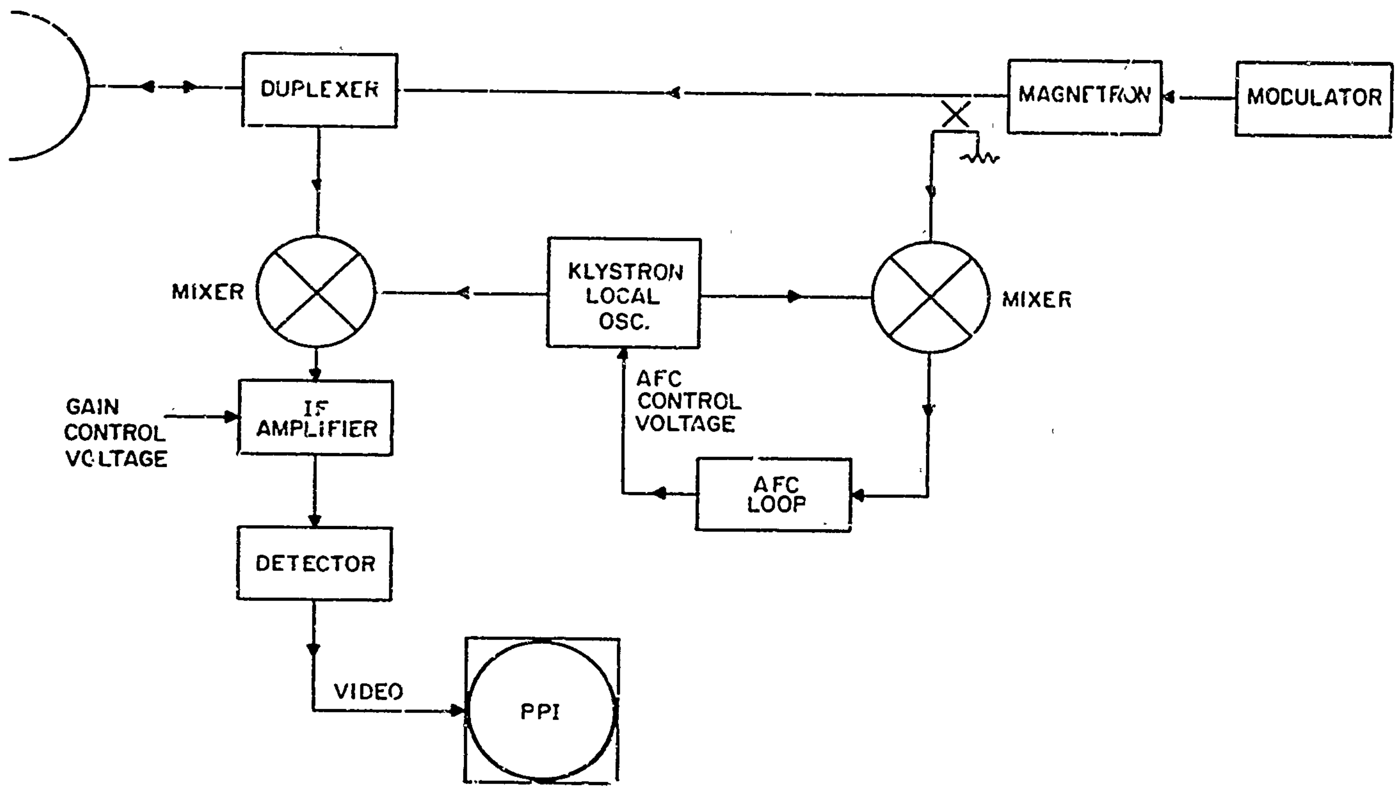


Figure 6 SIMPLIFIED RADAR BLOCK DIAGRAM

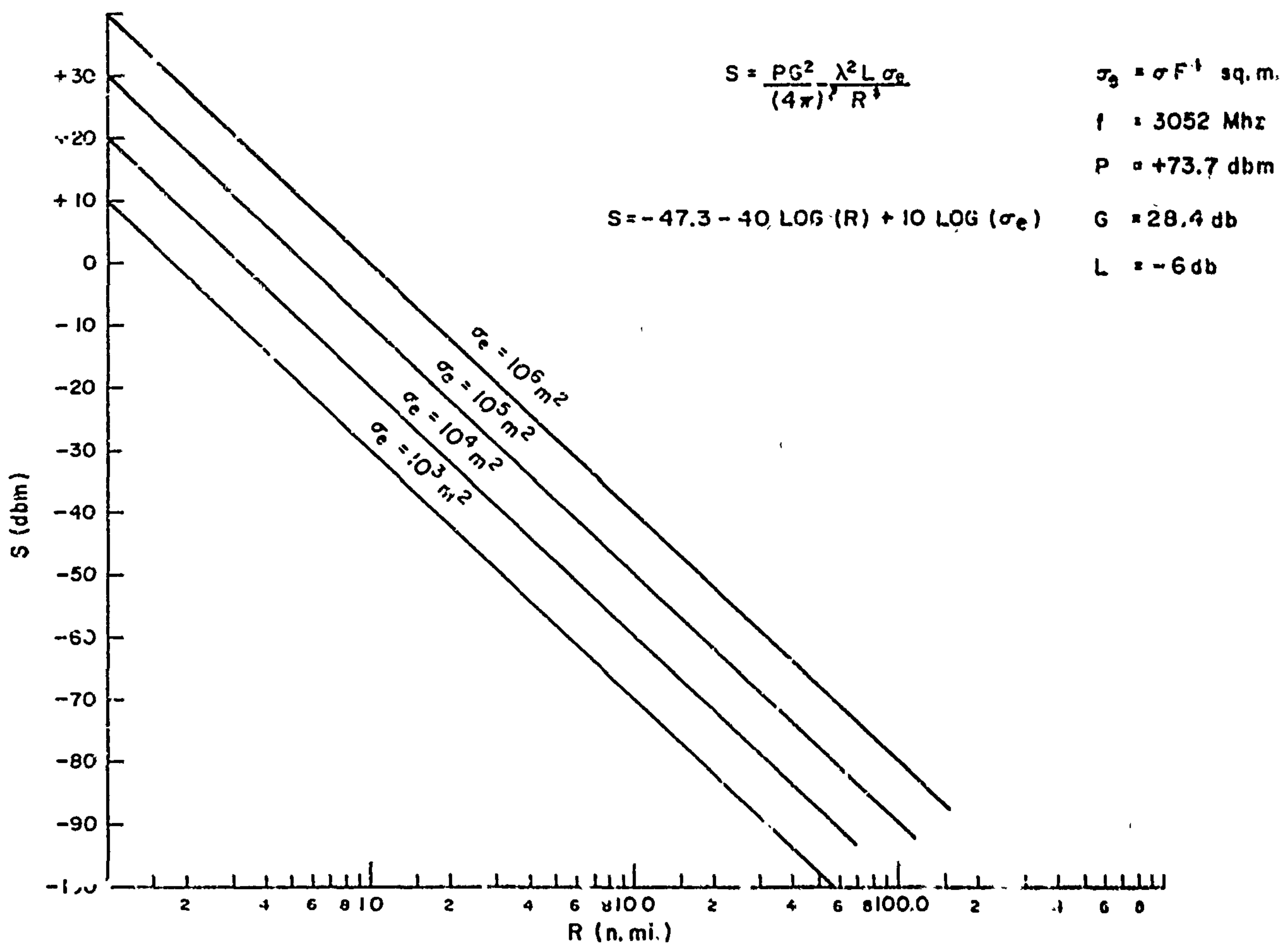


Figure 7 RECEIVE' SIGN'AL POWER vs. RANGE FOR VARIOUS RADAR CROSS SECTIONS (BASED UPON MEASURED RADAR PARAMETERS)

produces a voltage waveform which, when applied to the gain control of the I. F. amplifier, increases the gain in direct proportion to range to the fourth power. In this way the raw video signal level remains constant for a given size target independently of range. The STC waveform is obtained by integrating a sequence of equal width, time contiguous pulses whose amplitudes increase with range. Calibration is effected by first turning to zero the variable attenuator which precedes the antenna. Then test pulses corresponding to the power returned from a discrete of 1000 m^2 (from Figure 7) are injected into the radar sequentially at ranges of interest and the STC curve adjusted to produce a video voltage which just equals the reference voltage of the threshold. After calibration, a discrete which exceeds the threshold at any range is then known to be equal to or greater than 1000 m^2. By adjusting the variable attenuator, the threshold is automatically increased by twice the attenuator setting. During operation at Boston Hill, similar operation was obtained by attenuators inserted between mixer and I. F. amplifier.

SECTION III

EXPERIMENTAL PROCEDURE

A. PARAMETER MEASUREMENT

During this phase of the program, emphasis was placed upon the identification of sources of discretes. This information would be useful in the planning of future experiments, and would facilitate extrapolation of the results to the AWACS problem. In the experiment, therefore, considerable effort was expended in accurate range and azimuth measurement. Not all discretes at a given site could be studied by manual data collection, plotting and field survey, so that only the largest seen received detailed study. (Except for site #1 there were many more discretes greater than 10^3 m^2.)

The measurement of (1) radar cross section, (2) range, and (3) azimuth are described below. After determining range and azimuth, U. S. Geological Survey topographic maps were used for plotting the locations of discretes.

(1) Measurement of Radar Cross Section: Radar cross section was determined either by comparing the video levels of a discrete return and an R. F. test pulse on an A-scope, or by means of threshold adjustment using the attenuator in the waveguide to the antenna. Most measurements were made with the waveguide attenuator after it was established that the STC curve and attenuator scale gave appropriate accuracy; discrepancies of several tenths of a db were the largest observed when, from time to time, comparisons were made by the two methods.

(2) Range Measurement: Range measurement was made using the time delay feature of an oscilloscope with a delayed sweep. Based upon an accurate scope calibration, and correlation with returns from isolated objects at locations obtained from U. S. Geological Survey topographic maps (scale of 1:24,000, "7 - 1/2 minute" series), errors in absolute range measurement are believed not to have exceeded three hundred feet. When identifying the source of discretes, extreme care was exercised in both the delay measurement and the subsequent plotting of the range measurement on topographic maps.

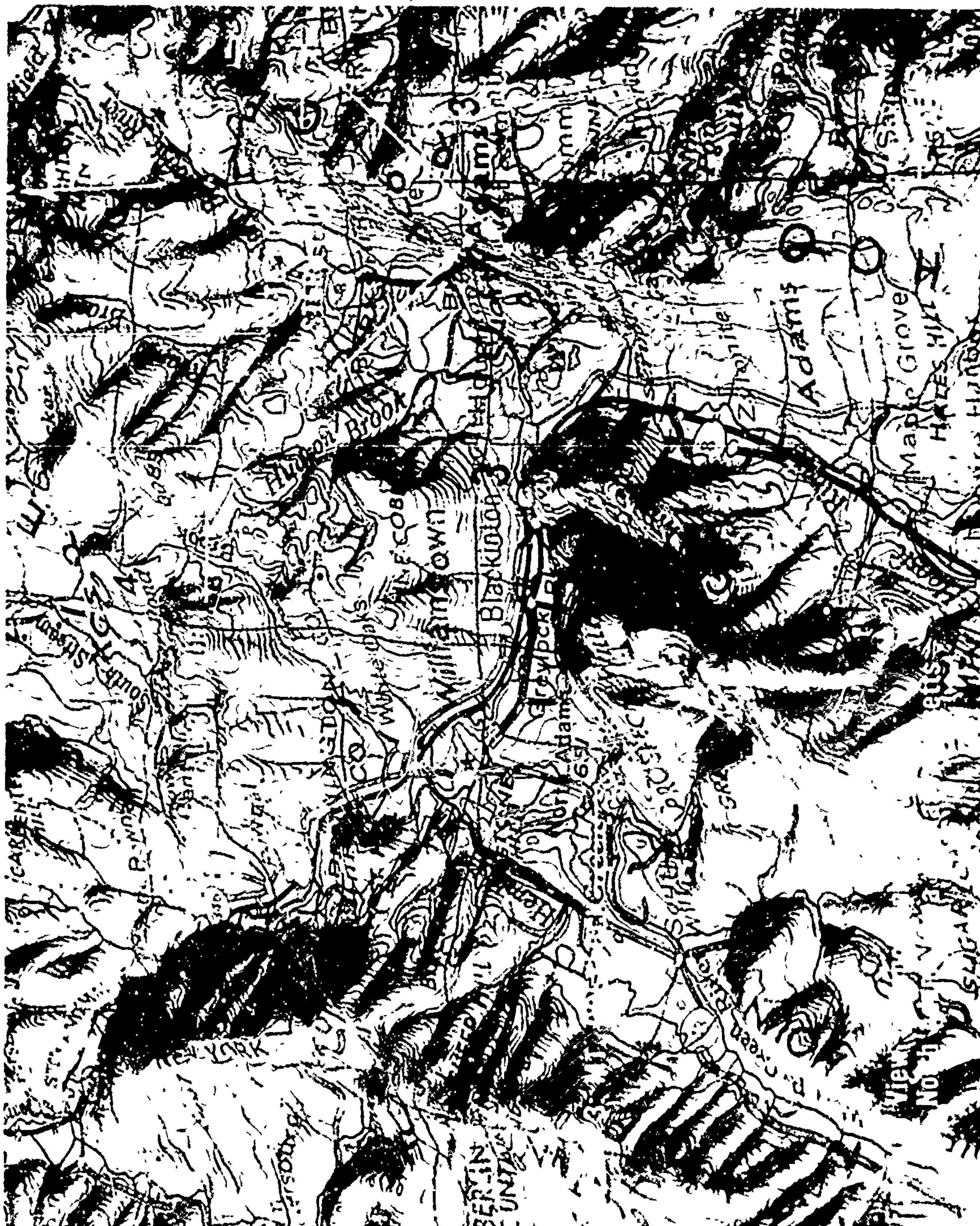
(3) Measurement of Target Azimuth: As discussed in an earlier report[3] the antenna pedestal is fitted with an azimuth "ring", graduated in intervals of 0.5 degrees, and a pointer fitted to the antenna. Mounted on the antenna is a telescope previously boresighted with the beam. Mounted on the rear outside wall of the cabin about two feet above the roof line is a detachable "tripod head" for the mounting of a "thirty second" engineer's transit. A distant object is sighted with the transit mounted on the truck. A point is placed on the ground some distance from the truck in line with the object. The transit is then "set - up" over the point. By means of the compass on the transit, the magnetic bearing of the line connecting truck and distant object is determined. The line is then referenced to true north by correcting for local magnetic declination. The antenna telescope is then focused on the distant object. From the known bearing to the distant object, true north on the azimuth ring and PPI can be deduced.

After north referencing the beam, bearing measurements can be made on a target of interest by "hand cranking" the antenna till an electrical maximum is observed on an A-scope and noting the corresponding angle on the azimuth ring. Overall accuracy is estimated to have been no worse than 0.25 degree or about 26 feet per mile of range.

B. SITE SELECTION

Figure 8 is a photograph of a portion of a three-dimensional map showing the area in western Massachusetts where the data was obtained. The vertical to horizontal exaggeration of the map scale is three to one (1:83, 333 and 1:250, 000 respectively). This area was selected because it provided the opportunity to obtain a relatively large range of grazing angles on urban areas. Most sites in mountainous regions do not "look down" onto population centers. Three sites are indicated on the map: "Hairpin Turn" (#1), "Western Summit" (#2), and "Mt. Greylock" (#3). At site #3, the radar was operated at several positions at the same elevation, thereby permitting a variation of azimuth angle with constant grazing angle.

Both Adams and North Adams are small cities; their populations are approximately 12, 000 and 20, 000 respectively. The population is more or less concentrated in areas of about a few square nautical miles in each case. North Adams contains light manufacturing operations; the plants are often converted brick textile mills.



SECTION IV

MEASURED RESULTS AND OBSERVATIONS

A. GENERAL

Some general observations are presented below as a preliminary to discussion of specific data acquired at each of the three sites.

(1) In general, atmospheric effects were more pronounced than previously experienced at Boston Hill. Measurement of radar cross section was observed to vary as much as two decibels on some days with a haze, and contrast seemed greatest between early morning when the valley was in shadow and midday when the sun was near the zenith. No attempt was made to study this effect in detail or to make cross section measurements at any specific time of day. Therefore, all values cited should be understood as having about a $\pm$ 2 decibel tolerance.

(2) In general, the lower the RCS of any discrete observed, the greater the short term fluctuation. This effect, observed with the antenna "searchlighting", is consistent with the Rice distribution that was recognized by Kerr as being an appropriate model.[4] As pointed out below, natural terrain showed a distinct type of fluctuation.

(3) Water towers do not exist in the area in which measurements were made, since open reservoirs provide the local water supply. Hence, no opportunity existed for comparison with results obtained at Boston Hill.

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(4) Local shadowing prevents a meaningful definition of areal density. It may be valid, however, to define a discrete density relative to the population density as qualified by grazing and azimuthal angle dependence.

(5) Grazing angle is obtained from the contour difference of the radar and the discrete as given by U. S. Geological Survey topographic maps.

B. RESULTS AT SITE #1

The characteristics of discretes studied at site #1 are detailed in Table 2. In examining the results from site #1, several observations may be made.

(1) Targets 1C, 1D and 1H show both the smallest RCS and the largest grazing angles. In the case of 1C, it is difficult to reach a specific conclusion as to reflecting mechanism. Similarly, target 1H was not sufficiently well identified as a source to permit a firm inference as to reflecting mechanism. In the case of target 1D, however, there is a strong suggestion that the side face of the mobile home is being viewed normally in the horizontal plane and at an angle off the normal in the vertical plane equal to the grazing angle.

(2) The inference gained from aspect angle considerations as cited above is reinforced by the general alignment of roof lines at right angles to the line of sight for targets 1A, 1B, and 1F. In the case of the other larger targets 1E and 1G, the complexity of the structures precludes the possibility of any firm inference. It seems likely that in Figure 10, the A-scope photo of returns from target 1B, the smaller return following that measured is due to the noncoherent combination of buses and the misaligned further

building while the more ideally oriented and nearer building is the source of the main return.

(3) In line with the observations on azimuthal dependence, it can be observed that few targets were observed in the business district of North Adams (yellow area in Figure 8). A majority of the observed discretes are north of the city i.e., about due west of the radar site. Such results may be due in part to the following circumstances. A detailed topographic map shows the business district to have a rough, but nevertheless distinct, street alignment parallel and at right angles to the north branch of the Hoosic River as it flows through the business district; the river trends westerly through the business district. However, the center of town is at a bearing of approximately 260°. Hence, structural components such as roofs and walls may have a general azimuthal misalignment in the context of highly directive reflectors.

(4) Many returns from the northeasterly side of hill 1640, the northern extension of Ragged Mountain, were observed but not recorded in detail. More detailed observations were made at site #2 on the returns from hills. Returns from hills were in the range $10^2 - 10^3$ m^2 at site #1 and were not clearly defined in azimuth or range. Figure 14, an A-scope photo taken at site #2 may be taken as typical of observations made at site #1.

(5) Much of the easterly side of the business district of North Adams lies in the shadow of a low ridge paralleling the Hoosic Mountain range, which no doubt accounts for the failure to see some discretes in this area of the business district.

TABLE 2 CHARACTERISTICS OF DISCRETES OBSERVED FROM SITE #1

Target	RCS ($db/10^3\ m^2$)	Range (n.mi.)	Bearing (degrees)	Grazing Angle (degrees)	Description	Comment
1A	+5	1.70	305	3.03	Barn with metal roof	Outside business district; barn roof line approximately normal to line of sight; wooden silo with metal roof
1B	+8	1.50	275	3.92	School bus depot w/two metal bldgs.	Outside business district; see Fig. 9a and 9b; the nearer building roof line is approximately normal to line of sight. See Figure 10 for A-scope photo.
1C	-1	1.03	327	5.73	House	Outside business district; see Figure 11; only metal visible is "flashing" on roof edge; corner reflector effect(?)
1D	4	0.73	282	7.75	Mobile Home	Outside business district; painted metal construction; longitudial axis approximately normal to line of sight.
1E	+7	2.31	253.5	4.0	Building(?) with metal roof	N. Adams business district; no obvious significant orientation; density of buildings precludes exact determination of source; probably a single building; see figure 12 for A-scope photo.
1F	+5	4.82	260.5	3.58	Metal Aircraft Hanger	Approximately ten degree angle between normal to roof line and line of sight; see figure 13.
1G	+5	2.47	256.5	3.97	Building(?)	N. Adams business district; exact source undetermined; area contains large metallic signs and highway overpass with steel components (railings, etc.)
1H	-4	1.58	26(	4.17	Residential area, N. Adams	At edge of business district; probably a metal roof garage.

(a)

(b)

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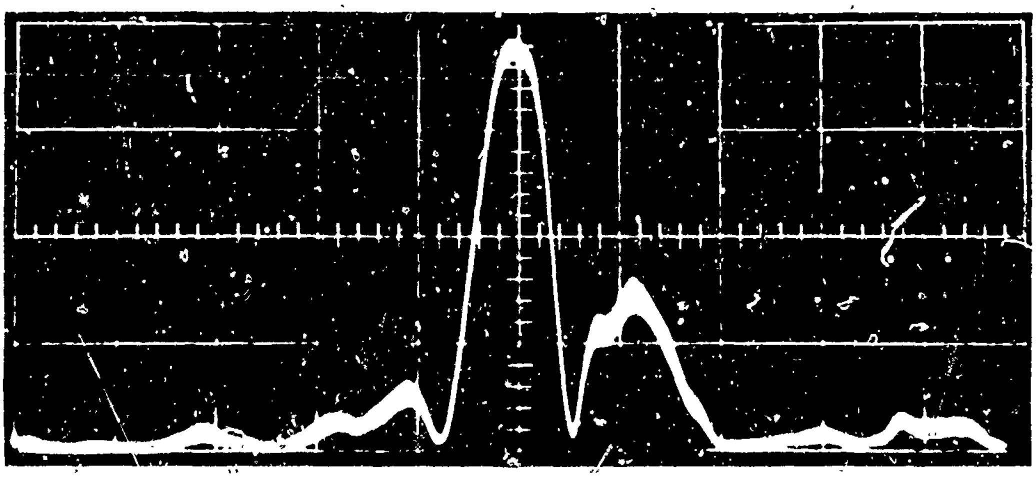
Figure 9 VIEWS OF TARGET IB



VERTICAL SCALE: UNCALIBRATED
HORIZONTAL SCALE: 0.5μSEC/CM (250 FT/CM)
EXPOSURE TIME: 1 SECOND

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Figure 10 A-SCOPE PHOTO OF RETURNS FROM TARGET 1B

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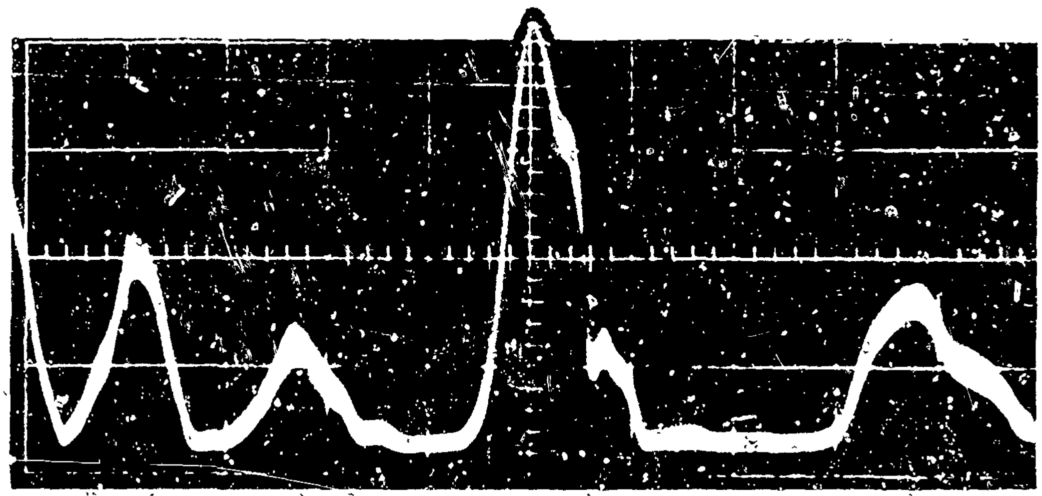
Figure 11 VIEW OF TARGET 1C



VERTICAL SCALE: UNCALIBRATED
HORIZONTAL SCALE: 0.5μSEC/CM (250 FT/CM)
EXPOSURE TIME: 1 SECOND

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Figure 12 A-SCOPE PHOTO OF RETURNS FROM TARGET 1E

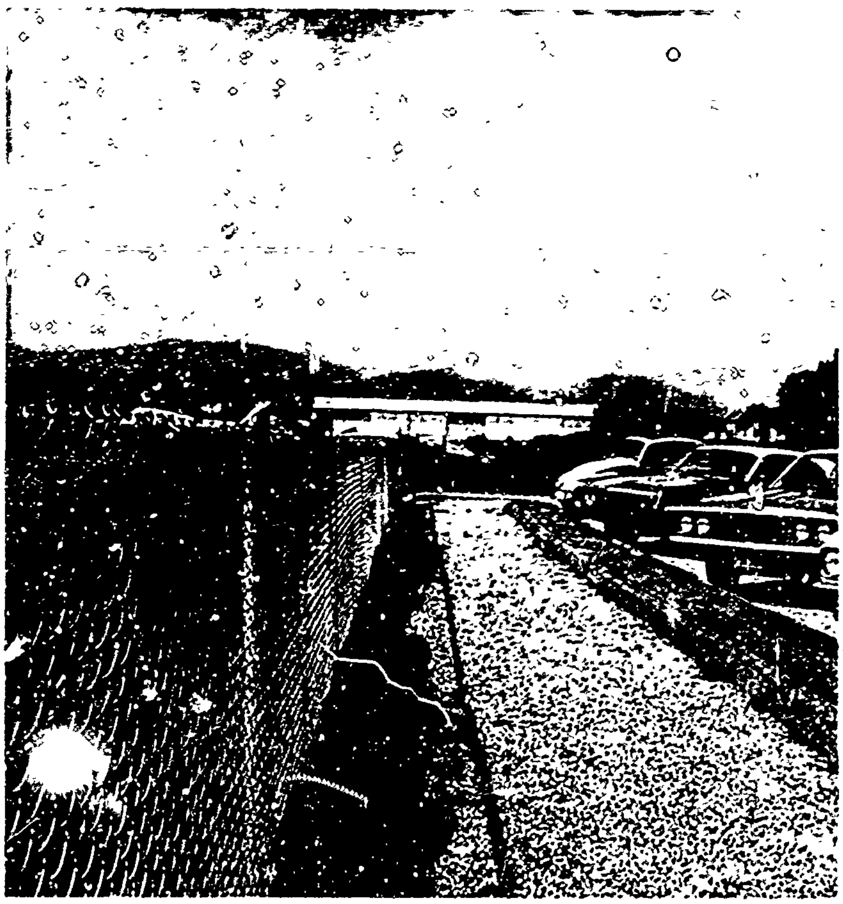

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Figure 13 VIEW OF TARGET IF

C. RESULTS AT SITE #2

The characteristics of discretes studied at site #2 are detailed in Table 3. In examining the results from site #2, several observations may be made.

(1) The center of North Adams is at a bearing of about 280° from site #2. With reference to the "misalignment" noted in paragraph B.3 on the preceding page, North Adams has about the same amount of misalignment from site #2 as site #1. This would appear to account for the relatively few discretes (three) observed in the business district.

(2) The general trend of structural orientation normal to the line of sight again prevails from site #2. Hence, the inference of azimuthal dependency is further reinforced.

(3) The generally larger range of cross sections in comparison with site #1 would appear to be due to the physically larger structures seen at site #2. No clearly discernible grazing angle dependence can be inferred, since, even though 2E and 2F have large RCS and the largest grazing angles, they are complex reflectors.

(4) It is interesting to note that among the largest discretes identified from site #2, none were those observed from site #1. In fact, in attempting to find those from site #1 only two could be recognized, at values of RCS well below $10^3 m^2$.

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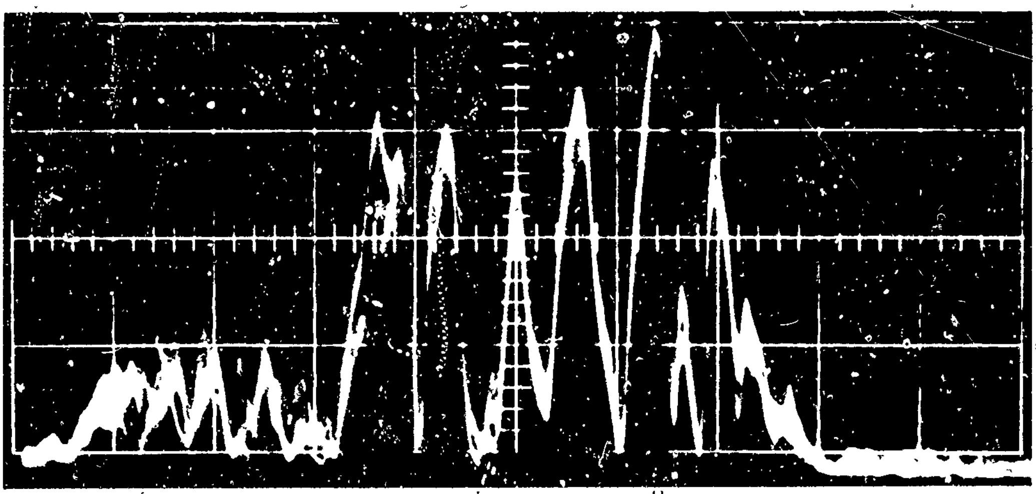
TABLE 3 CHARACTERISTICS OF DISCRETES OBSERVED FROM SITE #2

Target	RCS ($db/10^3\ m^2$)	Range (n.mi.)	Bearing (degrees)	Grazing Angle (degrees)	Description	Comment
2A	+ 6.5	4.73	239	1.8	Side of Mt. Greylock (Mt. Fitch)	Figure 14 illustrates fluctuation peculiar to large non-manmade discretes; range and azimuth variable
2B	+ 17.5	2.22	261.5	4.38	House with aluminum siding(?)	Edge of N. Adams business district. Probably aluminum sided house in residential neighborhood; roof line approximately normal to line of sight.
2C	+ 5.0	5.17	27[illegible].5	2.62	Barn with metal sides and roof	Located in Williamstown; roof line approximately normal to line of sight; see Figure 15.
2D	+ 7.0	3.4	272	4.26	"Supermarket"	Located in Williamstown; large facade and metalic covered walkway; see Figure 16.
2E	+ 10	2.13	272.5	6.05	Factory Building	N. Adams business district; front approximately normal to line of sight ; large expanse of window with 18 inch by 12 inch metal frames; see Figure 17 and Figure 18 for A-scope photo.
2F	+ 11	2.20	276.5	5.97	Factory Building	Sprague Electric plant in N. Adams business district; most probably metallic air conditioning super-structure; see Figure 19; Figure 20 for A-Scope photo.
2G	+ 9	5.02	274.5	2.79	Mobile Home Park with Metal Barn	Located in Williamstown; complex assemblage of man-made discretes; see Figure 21; A-Scope photo, Figure 22, shows that though extended in range there is little fluctuation; metallic rear wall of barn approxi mately normal to line of sight.

TABLE 3 (cont'd)

2H	+ 9	5.25	4.5	.	Steep face of Mountain	Located in Vermont; fluctuation typified by Figure 14: grazing angle definition not appropriate to distributed slanted surface.
2I	+ 3.5	7.0 - 7.08	6.25	.	Steep Face of Mountain	Located in Vermont; see Figure 14, for typical fluctuation; grazing angle definition not appropriate to distributed slanted surface.



VERTICAL SCALE: UNCALIBRATED
HORIZONTAL SCALE: 0.5μSEC/CM (250 FT/CM)
EXPOSURE TIME: 1 SECOND

1A-33,464

Figure 14 A-SCOPE PHOTO OF RETURNS FROM TARGET 2A

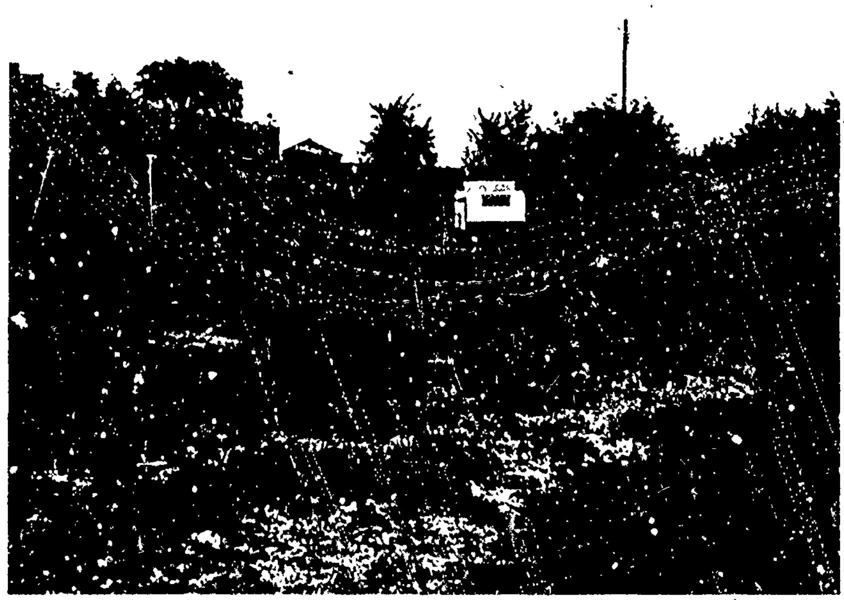


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Figure 15 VIEW OF TARGET 2C

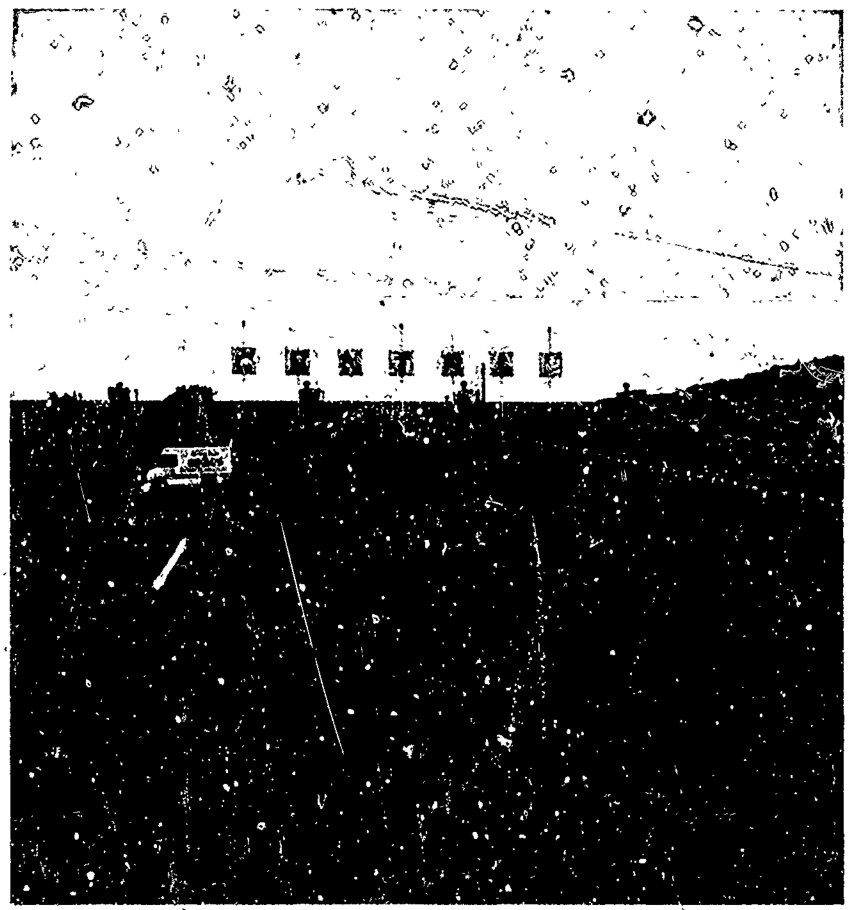

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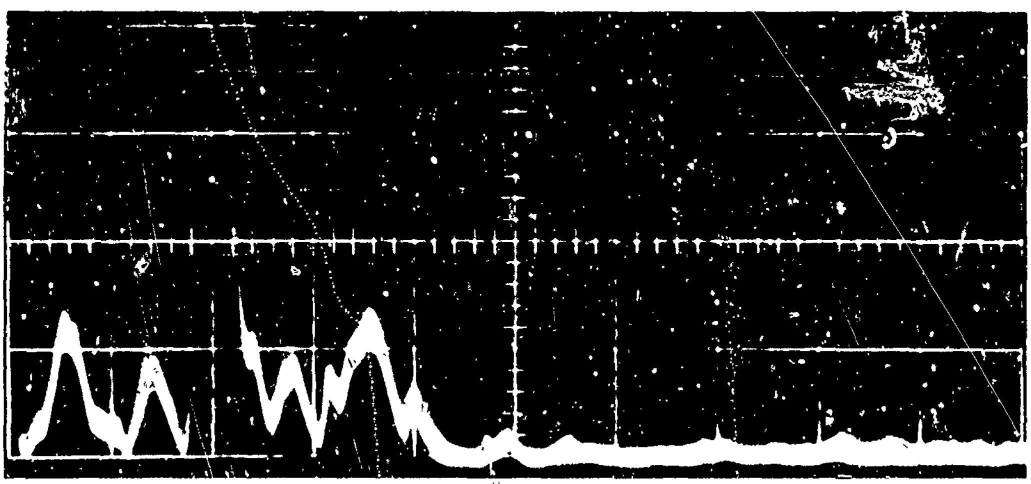
Figure 16 VIEW OF TARGET 2D

1A-33,467

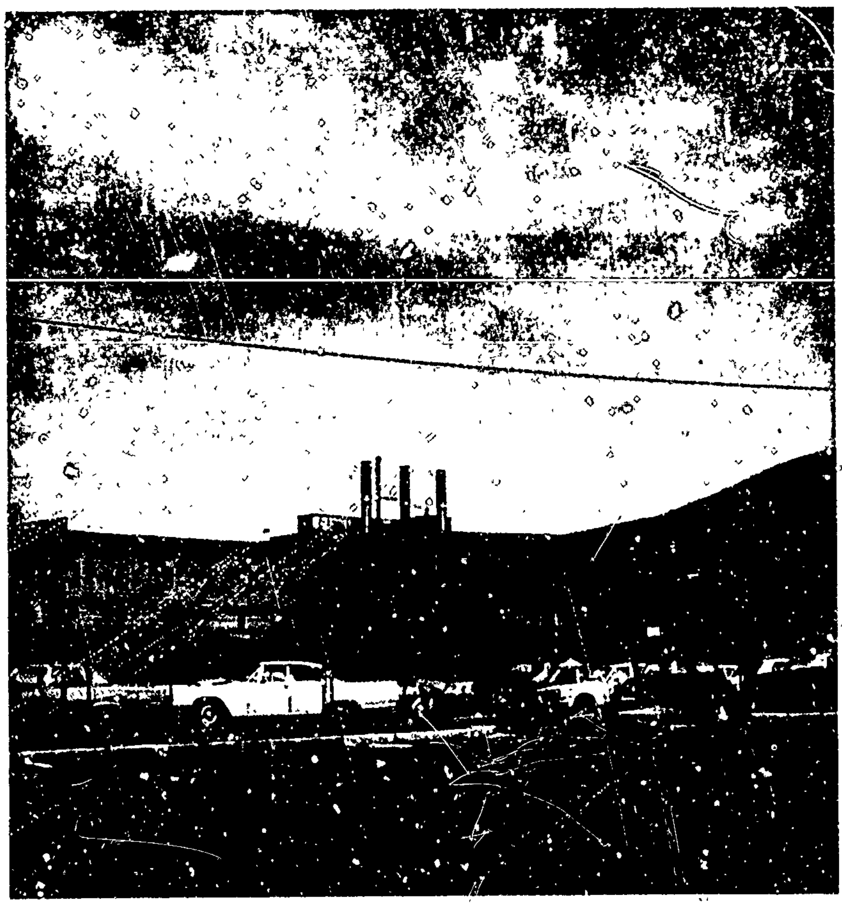
Figure 17 VIEW OF TARGET 2E



VERTICAL SCALE: UNCALIBRATED
HORIZONTAL SCALE: 0.5μSEC/CM (250 FT/CM)
EXPOSURE TIME: 1 SECOND

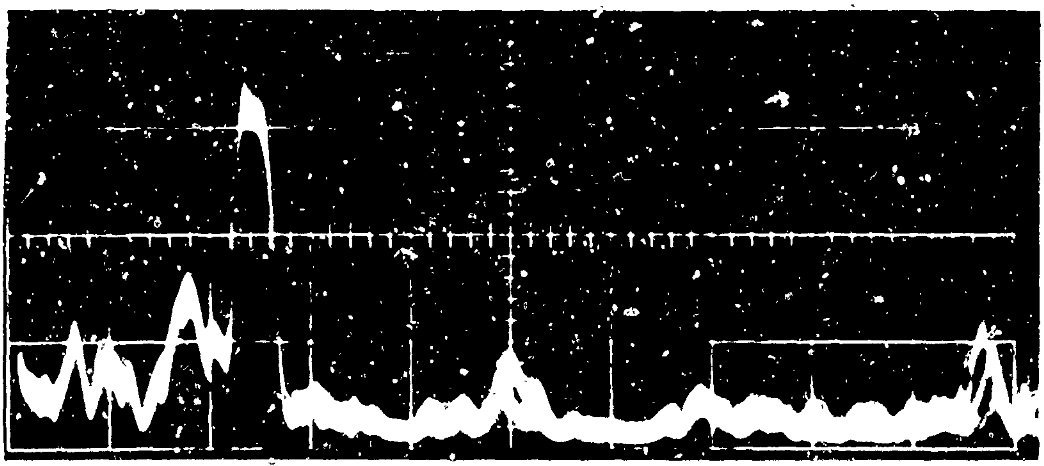
1A-33,468

Figure 18 A-SCOPE PHOTO OF RETURNS FROM TARGET 2E



(A-33,469)

Figure 19 VIEW OF TARGET 2F



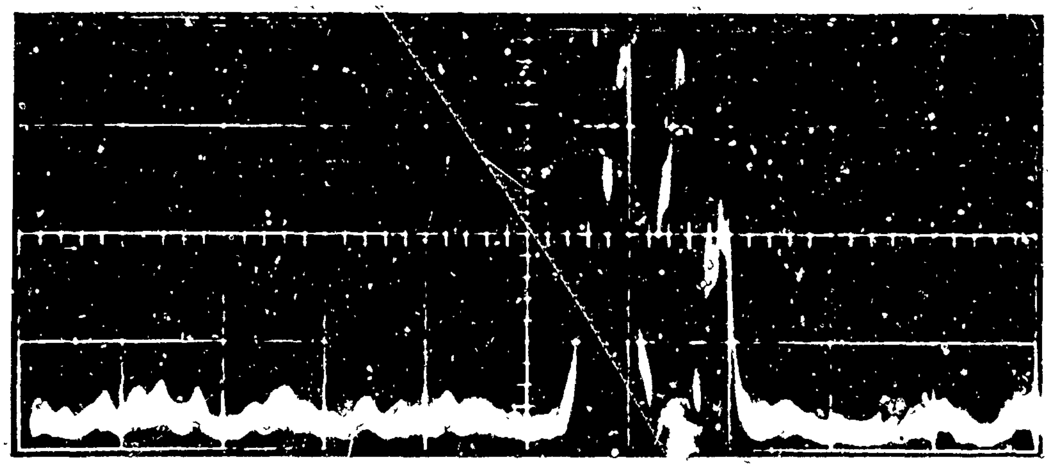
VERTICAL SCALE: UNCALIBRATED
HORIZONTAL SCALE: 0.5μSEC/CM (250 FT/CM)
EXPOSURE TIME: 1 SECOND

1A-33,470

Figure 20 A-SCOPE PHOTO OF RETURNS FROM TARGET 2F

IA-33,471

Figure 21 VIEW OF TARGET 2G



VERTICAL SCALE: UNCALIBRATED
HORIZONTAL SCALE: 0.5μSEC/CM (250 FT/CM)
EXPOSURE TIME: 1 SECOND

IA-33,472

Figure 22 A-SCOPE PHOTO OF RETURNS FROM TARGET 2G

D. RESULTS AT SITE #3

The characteristics of discretes studied at site #3 are detailed in Table 4.

At site #3 it was possible to locate the radar in five positions at constant elevation thereby permitting a study of the variations of discrete RCS with azimuth at a constant grazing angle. Figures 23, 24, 25 show the variation of RCS with azimuth angle.

The following observations are made:

(1) As with sites #1 and #2, the largest discretes are man made.

(2) Where a simple regular shape (e.g. a metallic flat plate) is obvious, there is a generally favorable alignment when considered as a highly directive reflector.

(3) Physically large structures, or aggregates of structures, are the source of discretes.

(4) The sides of hills are among the smallest discretes observed.

(5) Sections of Adams on the west bank of the Hoosic River are in shadow owing to the radar's location on the crest of Mt. Greylock.

(6) Figure 26 summarizes the RCS as a function of grazing angle. An umambiguous trend in RCS as a function of grazing angle cannot be discerned. However, the large values of RCS observed for 3F and 3H could result from large physical size offsetting a reduction in gain from illumination off the normal.

TABLE 4 CHARACTERISTICS OF DISCRETES OBSERVED FROM SITE #3

Target	Figure Showing RCS	Range (n.mi.)	Bearing (degrees)	Grazing Angle	Description	Comment
3A	Figure 23	4.86	29.75	5.15	Hospital(?) N. Adams	Residential area at edge of business district; only large structure with metallic superstructure.
3B	Figure 23	6.27	30.75	3.53	Farm Bldg's w/metal roof shed(?) N.Adams	Outside business district approximately 200 feet from target 1A.
3C	Figure 23	6.23	31.5	3.57	Rural House N. Adams	Outside business district; in center of homes; aluminum sided house(?).
3D	Figure 23	5.20	48.5	4.03	Mobile Home Park, N.Adams	Outside business district; approximately 30 units in two columns of parallel units with long axis approximately normal to line of sight.
3E	Figure 24	7.93	8[illegible]	2.13	Abandoned automobiles	Mountain meadow; three passenger vehicles parallel parked approximately six feet apart and one parallel to front bumpers of the other three offset about six ft.
3F	Figure 24	3.22	101	6.70	Metal Roof barn, Adams	Outside business district. Long shed-like (≈40') structure w/roof line approximately normal to line of sight.
3G	Figure 24	2.36	103	11.25	Metal Sheds, Adams	Business district; three all-metal sheds w/roof lines parallel to line of sight. No separation between long walls.
3H	Figure 24	2.39	106.5	10.55	Building, Adams	Business district; no obvious single building among a group of industrial buildings.
3I	Figure 25	4.27	168.5	5.87	Mobile Home Park, Cheshire	Rural area southeast of Adams; units occupy an area approximately 1000 ft. by 1000 ft.; orientation of long axis of units approx. parallel to line of sight

TABLE 4 (CONT'D)

3J	Figure 25	3.86	84.25	4.40	Side of Hill	Bare rock face approximately 30 feet high.
3K	Figure 25	8.11	325.5	–	Side of Hill	Return from a steep face of mountain with vegetation; approximately normal to line of sight. Grazing angle definition not appropriate.
3L	Figure 25	4.32	141	4.38	Rural Building	Rural area southeast of Adams.
3M	Figure 25	2.28	104	11.43	Dual Family Dwelling	2-1/2 Story structure with aluminum siding.

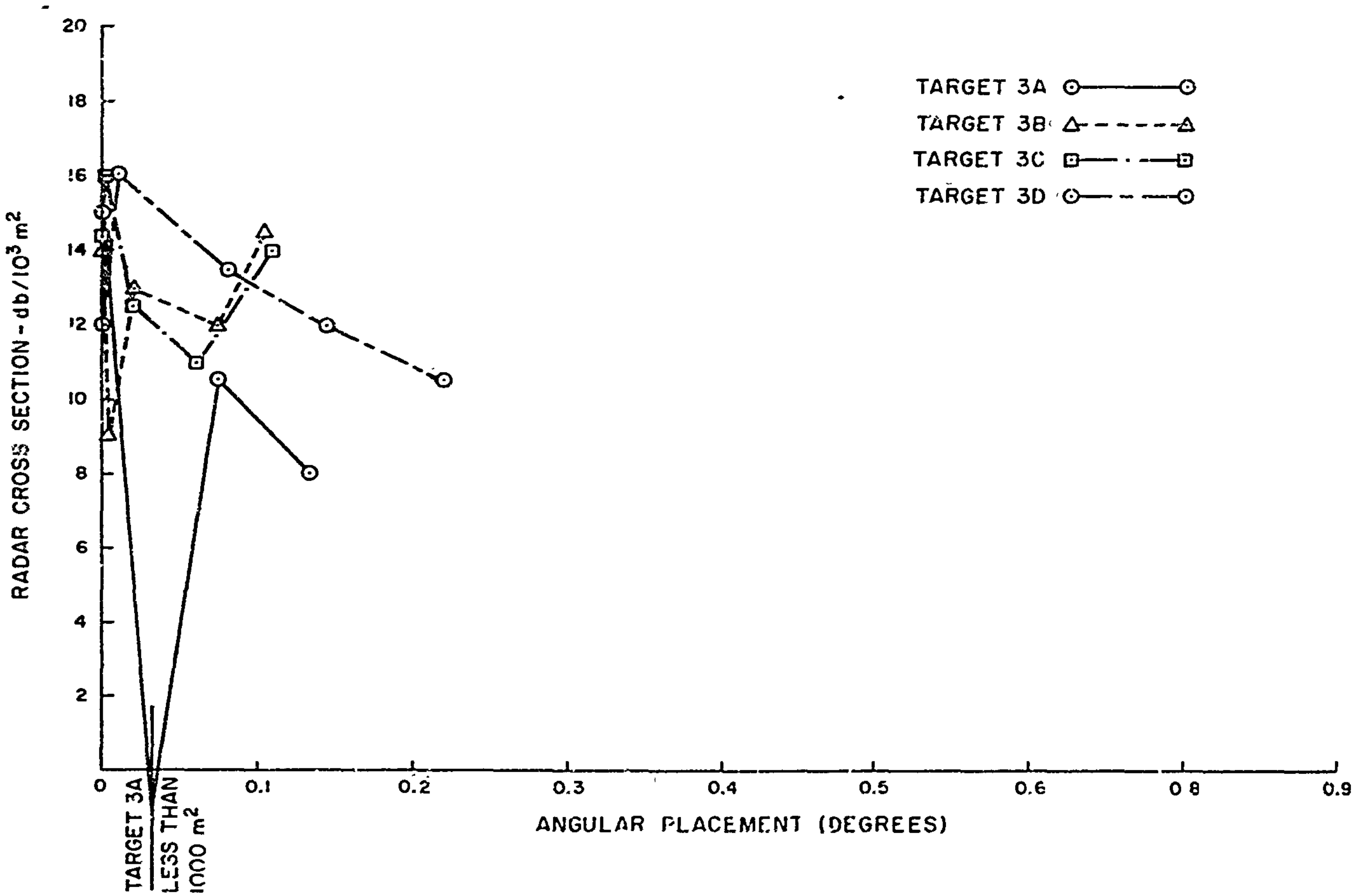


Figure 23 AZIMUTHAL DEPENDENCE OF RADAR CROSS SECTION FOR TARGETS 3A THROUGH 3D

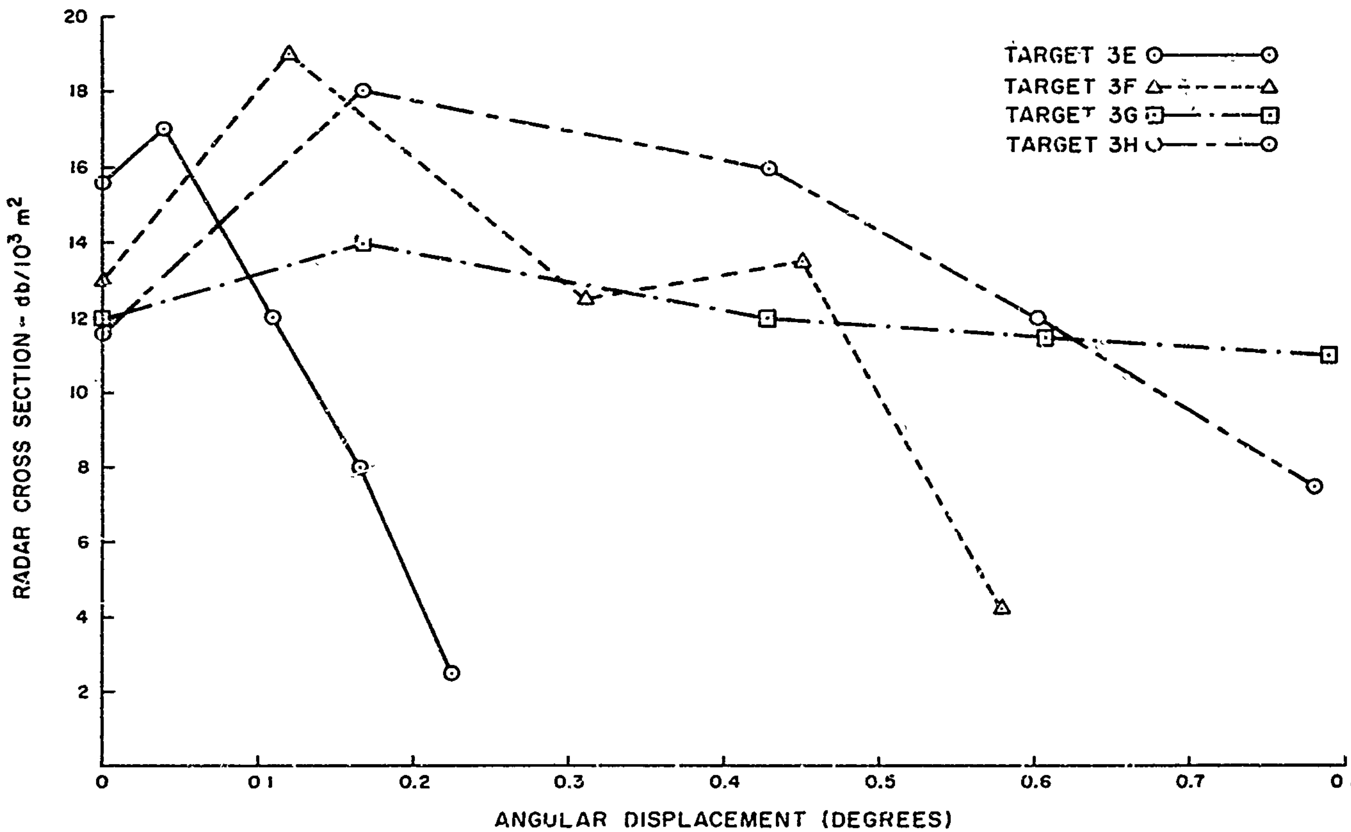


Figure 24 AZIMUTHAL DEPENDENCE OF RADAR CROSS SECTION FOR TARGETS 3E THROUGH 3H

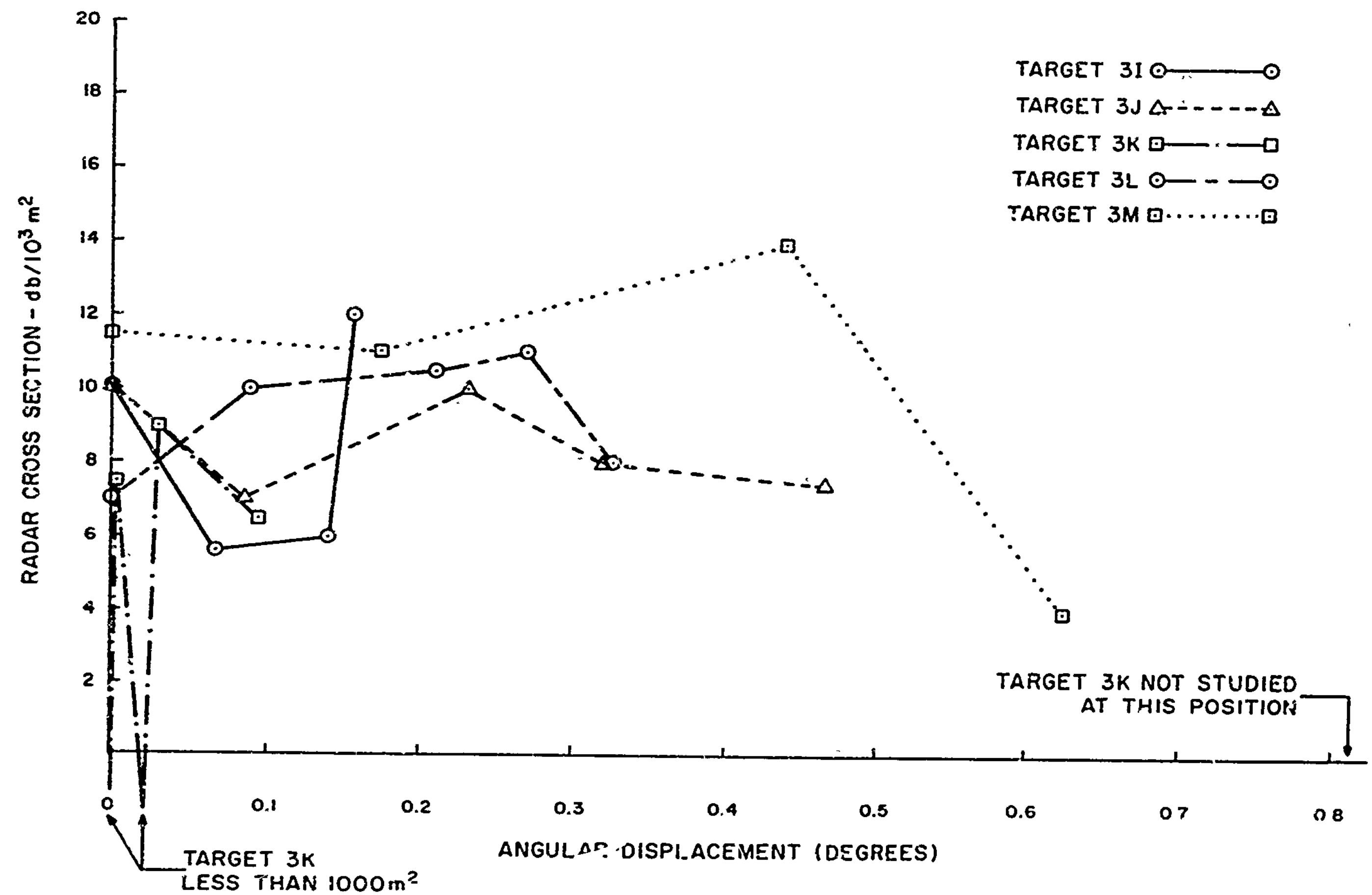


Figure 25 AZIMUTHAL DEPENDENCE OF RADAR CROSS SECTION FOR TARGETS 3I THROUGH 3M

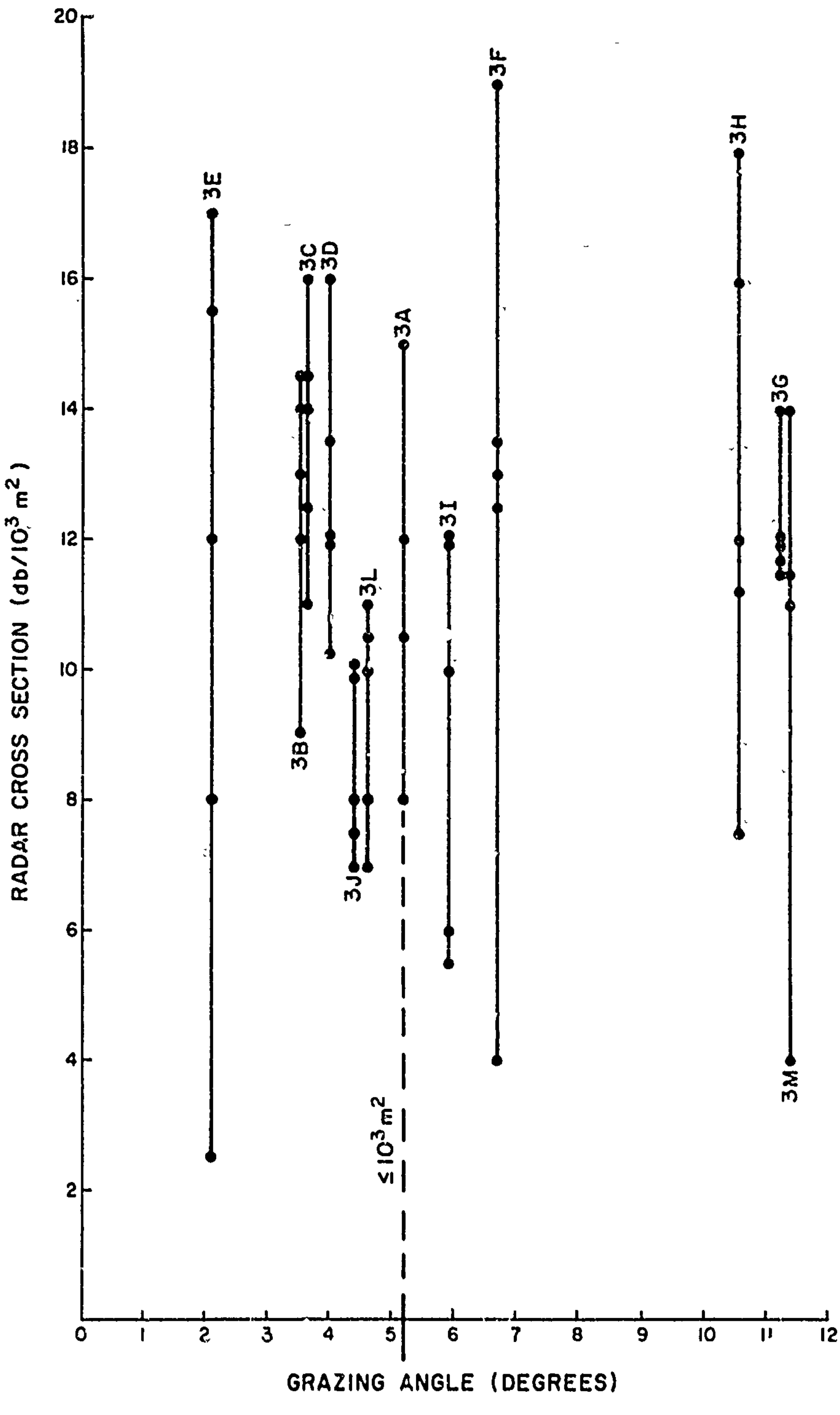


Figure 26 RADAR CROSS SECTION vs. GRAZING ANGLE FOR TARGETS 3A THROUGH 3M

SECTION V

SUMMARY AND CONCLUSIONS

The results of discrete measurements at the three sites may be summarized as follows:

(1) Site #1:

a. Eight discretes studied above 100 m^2

b. Largest discrete 6300 m^2

c. Five discretes greater than 1000 m^2

d. Range of grazing angles 3.03° to 7.75°

e. Typical sources: Structures with extensive metallic surface

Site #2:

a. Nine discretes studied all above 1000 m^2

b. Largest discrete 57,000 m^2

c. Three discretes greater than 10,000 m^2

d. Range of grazing angles 1.8° to 6.05°

e. Typical sources: Commercial buildings; smaller discretes due to hills

Site #3:

a. Thirteen discretes studied above 1000 m^2

b. RCS dependent upon azimuth angle

c. Two discretes "disappeared" at two radar positions.

d. Largest discrete 80,000 m^2

e. Range of grazing angles 2.13° to 11.25°

f. Typical sources: Structures with extensive metallic surface.

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(2) The RCS values observed were generally smaller than those recorded at Boston Hill, the largest being about 80,000 m^2.

(3) The larger discretes, i.e., those selected for study were all associated with man-made structures.

(4) The larger discretes give a returned signal that shows little fluctuation.

(5) Dependence of discrete RCS upon azimuth was confirmed in a few cases. Elevation dependence may be inferred from the nature of the reflecting structures.

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2. IBID, pg. 18 et. seq.

3. IBID, pg. 25

4. Kerr, D. E., "Propagation of Short Radio Waves", Vol. 13 Radiation Laboratory Series, pg. 550 et. seq.